5. SAMPLING PROTOCOLS

INTRODUCTION

Throughout the development of the monitoring program, GRYN has emphasized three elements: (1) the applicability of our program, (2) the reliability (i.e., scientific defensibility) of our program, and (3) the feasibility of our program. These elements have been addressed somewhat independently in previous chapters. This report is intended to provide the overall framework by which our entire program fits together. Similarly through the monitoring protocols described in this chapter, the pieces are woven together to form a coherent picture for a given vital sign or suite of vital signs. Through the protocols we enable the reader to see by whom, how, why, where and when these pieces fit together. Another intention of this chapter is to illustrate how these pieces contribute to our major thematic elements of applicability, reliability and feasibility of our vital signs. In keeping with this intention, a conceptual diagram of how these pieces contribute to these thematic elements is presented in Figure 5.1.

GREATER YELLOWSTONE NETWORK PROTOCOLS

The GRYN is currently developing monitoring protocols for 12 vital signs planned for implementation within the next 3-5 years. The relationship between vital signs and protocols is illustrated in Table 5.1. In addition the GRYN is developing a regulatory water quality monitoring protocol specially to address surface waters that are listed as 303 (d) impaired by either the state of Wyoming or Montana. The schedule for implementation is further described in Chapter 9.

PROTOCOL DEVELOPMENT

Background

The background section of our monitoring protocols is intended to describe the history and context for a given vital sign. This is intended to serve three distinct purposes. The first purpose of this section is to lay out the rationale for why this vital sign was chosen to be monitored. The second purpose is to provide the foundation and substance from which the specific monitoring objectives are derived. The third purpose is to describe the context within which this vital sign fits within our overall monitoring program.

1. THREATS AND CONCERNS

Many changes in the status or trend of the GRYN vital signs can result from being influenced by a known threat or concern for a given vital sign or in some cases changes in the status or trend of a vital sign can itself be a threat or concern for other vital signs. This section describes our current state of knowledge for the threats and concerns for a given vital sign in the GRYN. Wherever possible, we have tried to distinguish the extent of the empirical evidence for a given

TABLE 5.1 The GRYN has identified 12 vital signs summarized in 10 protocols that are targeted for implementation. In addition the GRYN is developing a regulatory water quality monitoring protocol specifically to address surface waters that are listed as 303 (d) impaired by the state of Montana or Wyoming.

Vital Sign	Protocol
Climate	Climate
Soil structure and stability	Soil structure and stability
Arid seeps and springs	Arid seeps and springs
Stream flow	Stream flow
Water chemistry	Integrated Water Quality and Regulated Water Quality
Aquatic invertebrate assemblages	
Exotic aquatic assemblages	
Invasive plants	Invasive plants
Whitebark pine	Whitebark pine
Amphibians	Amphibians
Landbirds	Landbirds
Land use	Land use

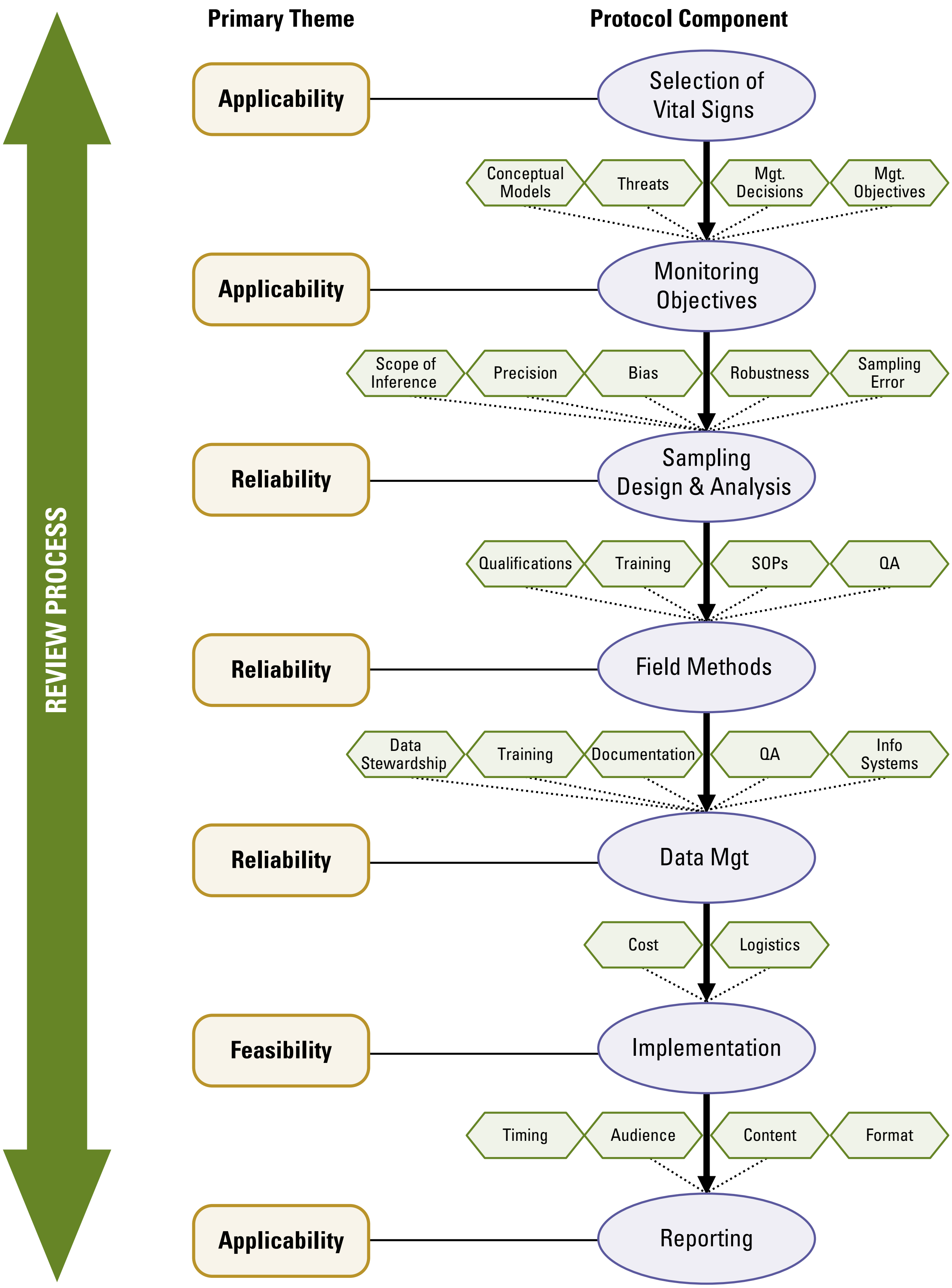

FIGURE 5.1 Conceptual framework for how the individual protocol elements contribute to the overall applicability, reliability and feasibility for a given vital sign or protocol.

threat or concern from that which is speculative. However, we have not limited our efforts to those for which empirical evidence exists. To the contrary, in some cases our monitoring effort is even intended to determine if a perceived threat exists, thereby providing empirical evidence for or against the speculated threats. We have also explicitly tried to extract out of reference material several concepts that will be necessary for selection of specific monitoring objectives and development of a sound sampling design. These included the known or expected magnitude of the threat or concern, the spatial extent of the threat or concern, and the time scales over which the threat or concern operates. Knowing, for example, whether or not the threat is cumulative or whether there are daily or seasonal patterns contribute to the development of the sampling design.

2. CONCEPTUAL MODELS

Conceptual models are constructed for a variety of purposes within the I&M program and have been previously discussed in Chapter 2. Relevant conceptual models are presented within each protocol as part of the background to better understand the context of a given vital sign. The I&M Program uses two types of conceptual models, stressor models and control models (Gross 2003). Stressor models identify the relationships between stressors (or drivers), ecosystem components and effects. In the context of GRYN protocols, stressor models help the network to identify which drivers and/or stressors have an influence on a given vital sign and/or what other vital signs (or other system components) this vital sign might influence as a driver or stressor. Given that stressor models do not typically incorporate feedbacks and interactions, they tend to be descriptive and retrospective. In contrast, control models represent key processes, interactions and feedbacks (Gross 2003). In the context of GRYN protocols, control models are likely to serve as a stronger foundation for understanding the mechanistic functioning of the ecosystem. As such, they may form a basis from which more quantitative and predictive models emerge. Thus, control models will likely play a key role as the GRYN evolves from design-based inferences toward model-based inferences (see Chapter 4).

3. OTHER MONITORING EFFORTS: PAST AND PRESENT

Also as part of the background, the past and existing efforts related to a given vital sign will be summarized. Existing efforts and partnerships need to be an integral part of the consideration for any protocol development. Maintaining the integrity of pre-existing data sets, understanding how GRYN efforts fit (or don't fit) within existing sampling designs, the experience of what has worked or not worked during past efforts, etc., all contribute to a foundation from which GRYN efforts can be built.

Measurable Monitoring Objectives

When reviewing the literature on ecological monitoring, there is virtually universal consensus that setting realistic, clear, specific and measurable monitoring objectives is a critical, but often difficult first step (e.g., Spellerberg 1991 Elzinga et al. 1998). Olsen et al. (1999) noted that "Most of the thought that goes into a monitoring program should occur at this preliminary planning stage. The objectives guide, if not completely determine, the scope of inference of the study and the data collected, both of which are crucial for attaining the stated objectives." They further went on to state that a "clear and concise statement of monitoring objectives is essential to realize the necessary compromises, select appropriate locations for inclusion in the study, take relevant and meaningful measurements at these locations, and perform analyses that will provide a basis for the conclusions necessary for meeting the stated objectives." It is for these reasons that the GRYN has taken the task of formulating monitoring objectives very seriously.

First we distinguish management objectives from monitoring objectives. Management objectives focus on the desired state or condition of the resource; whereas monitoring objectives focus on the measurement of the state or condition of the resource. In some cases monitoring objectives may directly reflect management objectives and provide the basis for evaluating achievement of the latter.

Despite the recognition of the importance of establishing good monitoring objectives, a clear understanding about what constitutes a good monitoring objective is often lacking. For this reason, a checklist of key elements for consideration was developed by the GRYN to ensure the quality of our monitoring objectives:

1. Does the objective clearly relate to one or more of the I&M program goals (see Chapter 1)?
2. Is the objective clear and specific?
3. Is the objective measurable?
4. Is the target population (i.e., intended scope of inference) clear?
5. Is it clear what parameters are being measured or estimated?
6. Have targeted levels of precision been identified?
7. Are there temporal patterns outside of the primary sampling interval (e.g., diurnal and seasonal patterns) that need to be considered?

8. Does the objective focus on the end result (i.e., what is being measured and when is it being measured or estimated), rather than the means (i.e., how) to achieve that result? (see Text box 5.1).
9. If the monitoring objective relates to a known threat or concern, is there also measurement of that threat or concern that would enable assessment of the association between changes in the vital sign and changes in that threat or concern?
10. If the monitoring objective is a science-based objective, is it better suited as a research question to complement monitoring, or is it better suited as part of the monitoring?
11. If the monitoring objective is a science-based objective (i.e., intended to increase our understanding of how the system functions or is affected by a particular stressor(s)), then is there a corresponding *a priori* hypothesis(es)?
12. Does the monitoring objective relate to one or more management objectives, and if so, has the management objective(s) been clearly stated?

Sampling Design

The sampling design ensures that the Inventory and Monitoring Program will provide information on the status and trends of our natural resources that is reliable and based on the best science possible. It is through the sampling design that we ensure that the data collected are representative of the target populations and sufficient to draw defensible conclusions about the resources of interest. The guiding principles regarding how the GRYN will approach sampling design are presented in Chapter 4. The sampling design section of the protocol provides the details of how those principles are realized. Some of the specific elements that will be included within the sampling design section of a given protocol are:

1. Units
    - Target population
    - Sample frame
    - Sample units
2. Sample size determination
    - Targeted detection level
    - Existing estimates of expected variation (if available), including source
    - Procedure for determining appropriate sample size (including power estimation)
3. Spatial Design
    - General spatial sampling design (random, systematic, cluster, etc.)
    - Logic or justification for design
    - Sample unit selection process
    - Stratification (including justification)
4. Temporal Design
    - Panel description (see Chapter 4)
    - Revisit design

Text Box 5.1

In a recent paper on common mistakes in designing biodiversity indicators, Failing and Gregory (2003) identified confusion of the means and the ends as one common mistake. It is quite common for agencies and organizations to express objectives in terms of the means to achieve an end, rather than the end itself. While this approach may be well suited for directing the actions of an organization, it does little for enabling better management decisions through science.

For example, consider a management objective, taken from a southeast land management agency:

Use fire to maintain and encourage dry prairie within pine flatwood habitats.

On the surface, this seems like a reasonable objective, and for the purpose of directing management actions, it is probably fine. However, when evaluating the degree to which this objective was accomplished, the agency determined that the objective was met 100 percent; not because dry prairie was established (which was never assessed), but because fire (the action) was used. For science to have been of much value in this context an alternative objective stated in light of the end rather than the means would have been required. An objective such as:

To maintain at least 20 percent of the overall area of pine flatwood habitat as dry prairie.

is better suited to determining whether the desired state or condition has been reached (although there certainly could be considerable refinement). Further, a corresponding monitoring objective that results in a measurement of the area of dry prairie as a percentage of the overall pine flatwood habitat is relatively easy to construct.

Field Methods

Our ability to reliably detect differences in resources over time or among sites is only assured if data are gathered in a consistent and well-documented manner (Beard et al. 1999). The field methods section of each protocol is intended to ensure consistent methodology. The detail of this section should be sufficient to ensure repeatability in light of changing personnel (Beard et al. 1999). Those aspects of field methodology that are repeated in different locations and/or by different personnel will be written in the form of a standard operating procedure (SOP). SOPs are detailed written instructions intended to ensure uniformity and consistency of a given procedure within the protocol. SOPs need to be easy to read and implement. SOPs also need to be reviewed and updated, if necessary, to ensure that they are current and relevant. The protocol will clearly define the strategy and procedure (i.e., via an SOP) for documentation and changes to existing SOPs (see section below on continual improvement).

Some of the specific elements that will be included within the field methods section of a given protocol are:

1. Pre-season preparation includes any preparation that need be completed before field efforts commence in a given sampling period including, but not limited to:
    - Permits
    - Equipment preparation
    - Training (may be part of an overall training SOP)
2. Data collection protocol(s) includes all field sampling procedures,
    - Data forms and data dictionary (may be part of an overall data management SOP)
    - Field measurement procedures
    - Safety procedures (may be part of an overall field safety SOP)
3. Post season processing
    - Lab processing (if applicable)
    - Voucher specimens (if applicable)
    - Equipment maintenance and storage

Data Management

Data management requirements for monitoring protocols include explicit procedures to enter, edit, document, store and archive data according to the scope of each vital sign protocol as well as for programmatic analysis and reporting. Standard operating procedures for data management activities address many of the common tasks among protocols. Chapter 6 summarizes the Network's overall plan for data management (Appendix VIII).

1. METADATA PROCEDURES

Developing and maintaining complete and accurate documentation of data sets is a fundamental requirement of the Program and the Network. Metadata establishes the basis for interpreting and appropriately using data in analyses and products by recording information about the data source(s), and the methodology by which the data were collected or acquired. The Network Data Manager works with other staff, partners and contractors to include directions in each protocol and standard operation procedures for:

- generating metadata using current Federal Geographic Metadata Committee's (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) and the Biological Data Profile of the CSDGM
- scheduling necessary reviews and updates
- recording full metadata in ESRI ArcCatalog© or in a structured format for import to ArcCatalog
- recording brief metadata in NPS Dataset Catalog
- distributing metadata at the NPS Natural Resources Metadata and Data Store.

2. OVERVIEW OF DATABASE DESIGN

Databases for monitoring protocols are designed to meet the data entry, quality assurance, and reporting or output requirements specified by the monitoring objective(s). Where possible, existing databases from other NPS units (from the NPS Protocol Clearinghouse) or external sources are adopted and adapted to promote consistency among data sets. Examples of database designs shared between the Network, other NPS units and other agencies include those for Whitebark pine (Whitebark Pine Ecosystem Foundation, a not-for-profit foundation), amphibians (Amphibian Research and Monitoring Initiative, USGS), and water quality (STOrage and RETrieval - STORET, Environmental Protection Agency). For monitoring protocols without suitable or available database designs, the Network will develop databases according to the NPS Natural Resource Database Template model for Microsoft Access and the ESRI Geodatabase model.

3. DATA ENTRY, VERIFICATION AND VALIDATION

Data management procedures for each protocol identify the tools, format and quality assurance requirements for data collected using the protocol. Step by step instructions and screen captured images from each database guide the user through the appropriate tasks. Each data record includes the name, version and date of the monitoring protocol used for data collection and processing. Data recording tools include both hardcopy field forms and electronic portable data recorders. Based on the requirements of the monitoring objective(s), data entry procedures include information about manual and automated quality controls, data verification procedures and data validation routines.

4. DATA ARCHIVAL PROCEDURES

Network protocols include instructions for archiving physical and digital data to support the long-term monitoring goals of the Program. Standard procedures address the long-term data storage requirements for most protocols and additional specifications are listed as necessary with each protocol's data management procedures. Each protocol discusses the plan to archive original or replicated data sets from other sources, and/or rely on external data repositories for certain data such as weather and streamflow data. The Network data management plan provides overall guidance for data archiving and addresses issues like future evolution of storage technology that permits or requires the migration of data to new platforms and storage media.

Analysis

Having a sound data analysis helps to ensure that the data we have collected using sound designs provide valid inferences about the resources we are trying to assess. Data analysis design should address the following questions.

1. Who is responsible for the data analysis?
2. What is the purpose of the analysis (parameter estimation, hypothesis testing, etc.)?
3. What are the analysis procedures? This section should provide a full overview of any anticipated analyses.
4. What is the validity of the estimate of certainty being obtained (i.e., standard error)?
5. At what frequency are routine analyses to be conducted?

Reporting

For the GRYN to be successful in communicating its purpose and progress toward inventory and monitoring, it is essential for the network to develop a clear and comprehensive strategy for reporting our results. This section of the protocol is a description of that strategy for a given vital sign (or as a general SOP) which includes at least the following elements:

1. Who is responsible for reporting?
2. Who is the intended audience?
3. At what frequency are reports to be made?
4. What is the anticipated content of the reports (general content, analyses and presentation)?
5. How will reports be made available (Web access, etc.)?

Quality Assurance/Quality Control

Quality assurance (QA) is a significant part of every monitoring program. It is the cornerstone of our ability to furnish reliable information. Quality assurance and control has been addressed in the context of data management in Chapter 6. However, quality assurance goes beyond data management and must be an integral component of all aspects of the GRYN program including field and laboratory systems for sample collection and measurement, survey design, equipment preparation, maintenance tasks, data handling and personnel training. The U.S.F.S. Forest Inventory and Analysis Program (FIA) identified three aspects of quality assurance (prevention, assessment and correction) that they refer to as the QA triangle (Figure 5.2).

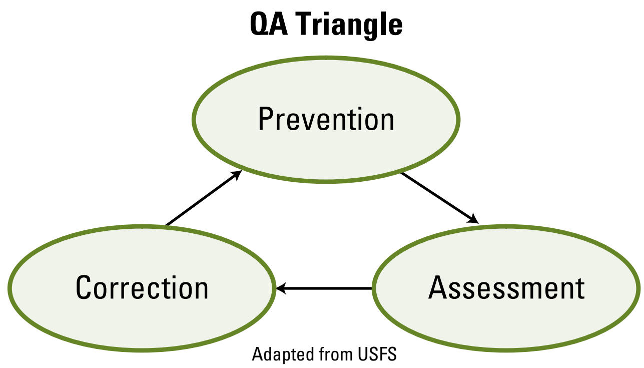

FIGURE 5.2 Quality assurance triangle adapted from U.S.F.S. Forest Inventory and Analysis Program (FIA).

The objectives of quality assurance are to assure that the generated data are meaningful, representative, complete, precise, accurate, comparable, and scientifically defensible. The network will establish and document protocols for the identification and reduction of error at all stages in the data lifecycle. Although specific QA/QC procedures will depend upon the individual vital signs being monitored and must be specified in the protocols for each monitoring vital sign, some general concepts apply to all network projects. Each vital sign protocol will include specifics that address quality control. These may include:

- Field crew training
- Standardized data sheets
- Equipment maintenance and calibration
- Procedures for handling data (including specimens) in the field
- Data entry, verification and validation

The Regulatory Water Quality Monitoring Protocol (O'Ney 2005) includes a QA/QC standard operating procedure (SOP) that addresses data representativeness, comparability, completeness, precision, systematic error/bias and accuracy. The SOP includes instructions on the use and frequency of quality control samples, such as blanks, duplicates and spikes and indicates the acceptable range and corrective actions for each QC sample. The SOP also includes instructions for completing/maintaining instrument calibration log books, field log books and chain of custody forms.

I. CONTINUAL IMPROVEMENT

In the context of the overall GRYN program, prevention is addressed through sound development of sampling design, data management and analysis. These have been addressed in greater detail in other chapters and in the corresponding sections of each protocol. Although prevention is extremely important, it is not sufficient by itself, due to changing programs, funding, environments, technologies, etc. Thus as part of each protocol, a section for continual improvement will also include the strategy for assessment (i.e., the review process) and correction.

1. Review Process

Each protocol will have a section (or general SOP) describing the strategy for periodic review. Such reviews may be periodic (planned at a predefined interval) or episodic (resulting from changing mandates, funding, priorities, etc.). The review process should permeate through all phases of our monitoring. It also should permeate through all of our thematic elements (i.e., applicability, reliability and feasibility), although it may not be the same review process for each element. Rather, the details of a given review should reflect which element(s) is being targeted. For example, a review intended to assess the scientific reliability is likely to be conducted by qualified scientists. In contrast, a scientific review panel may have little insight if a review is intended to assess whether or not the monitoring meets the needs of managers. Consequently, the review strategy should also clearly specify the purpose of the review and, at least in general terms, who should conduct the review.

2008 Program Review— A special case of the general review process for each protocol is that an overall program review is planned for 2008. This review would explicitly examine the suite of protocols using criteria discussed below for whether or not the individual protocols are meeting park information needs and I&M standards for scientific defensibility. More importantly, all of our initial twelve protocols should be completed by this time, and this review would be an opportunity to examine whether we have the best compliment of vital signs and/or have made the best compromises during implementation between the expected costs and benefits.

2. Process for Change

Determining the status and trends of selected indicators of the condition of park ecosystems is an essential and critical goal of the I&M program. Understanding the spatial and temporal scales over which change occurs is paramount to achieving this goal. We have considered the spatial and temporal scale in several elements of this report, including sampling design and implementation. However, many ecosystem attributes of interest operate at such long time scales that implementing a temporal sampling design requires a long-term commitment that enables teasing apart true change from environmental noise (i.e., variation). Thus, one of the key values of the I&M program is its long-term prospect. Frequent changes in monitoring protocols in the attributes being monitored and how they are being monitored would likely lead to a ever-weakening ability to meet the program goals, leading to erosion of support, further weakening the program, etc. Thus, at the outset the GRYN needs to be vigilant about disruptive change in our monitoring, while at the same time recognizing that changing resources and management regimes may require some degree of flexibility. The difficulty lies in finding the right balance between maintaining the necessary consistency to meet our program goals with enough flexibility to meet the challenges of changing natural and political environments. Thus, when making changes in protocols, the following questions should be addressed:

1. What are the criteria for determining whether or not a change is warranted? These should reflect the general themes identified above:
   - Reliability— The data are not reliable in their present form
   - Applicability— The data are not applicable to managers, the public, etc. in their present form
   - Feasibility— The data are not feasible to obtain in their present form (e.g., funding, logistics, priorities, etc.).
2. If it is determined that a change is required, what programmatic element needs to be changed?
   - Vital Sign?
   - Objectives?
   - Design?
   - Field Methods?
   - Data Management?
   - Analysis?
   - Reporting?

Note: Changing a vital sign or an objective is far more drastic than changing a reporting method. Thus the criteria for making changes to different elements may reflect their relative degree of severity.

3. What is the procedure for making the change?
4. What precautions will be taken to ensure that the revised protocol will be acceptable?
   - Pre-change reviews (based on planned changes)?
   - Post-change reviews (based on results from implemented changes)?
   - Testing concurrent with existing protocol?
   - Post-change analyses
5. How will the transition to the revised protocol be accomplished?
   - Will there be a period of overlap (*sensu* Newell and Morrison [1993]), if so how?

Operational Requirements

All of the elements that are required to implement the monitoring of a given vital sign need to be summarized in this section of the protocol, including:

1. Roles and responsibilities— This section of the protocol needs to include the specific roles of the personnel, including technicians, involved in sampling design, data collection, entry and analysis.
2. Qualifications— The necessary qualifications for the project coordinator, as well as the field technicians, should be stated here. An example of a skill that might be required of a field technician who will be monitoring for wildlife species is knowledge of wildlife habitat types.
3. Training— Often some form of on-site training before the field season begins is necessary. In some cases, such as when monitoring water quality, an agency other than NPS leads the training session. Any such situation should be noted here along with contact information for the training session and/or start date for on-site training due to seasonal limitations on sampling (i.e. sampling must occur during June and July; therefore, training must occur prior to June).
4. Annual workload and field schedule— This section of the protocol needs to explain the general timing and frequency of sampling. Also included here are the number of days needed for sampling, the number of personnel needed for each stage of sampling and the number of samples to be collected during each field day. If the data are coming from another source (i.e. climate stations), include here the timing of data collection (i.e. when and how often) and the contact information for the collecting agency.
5. Facility and equipment needs— This section of the protocol should include a list of all facility and equipment needs for each group of field personnel involved in sampling, along with a list any equipment sharing possibilities (and appropriate contact information where necessary).
6. Start-up costs and budget considerations— It is important to include all costs in the protocol. These costs should include all personnel, travel, space needs, laboratory analysis costs, new equipment needs and/or equipment sharing costs and equipment maintenance and storage costs.

PROTOCOL SUMMARY INFORMATION

The full protocols are developed as stand alone documents beyond the scope of this report. However, a complete summary of their development is presented in Appendix VII and in Table 5.2 we present a more abbreviated version of some of the key information contained within each protocol.

TABLE 5.2 Key information from each protocol including justification for why the vital sign is being monitored, the specific monitoring objectives and in which parks the protocol will be implemented. Monitoring objectives are revised and updated as protocols are completed.

Vital Signs	Justification[1] and Monitoring Objectives[2]
Climate	**Protocol name:** Climate **Justification:** Climate is a primary driver of almost all physical and ecological processes in the GRYN. Climate controls ecosystem fluxes of energy and matter as well as the geomorphic and biogeochemical processes underlying the distribution and structure these ecosystems (Jacobson et al. 1997, Schlesinger 1997, Bonan 2002). Global surface temperatures, in particular, have risen by 0.6 °C ± 0.2 over the past century (IPCC 2001). These global-scale changes will inevitably lead to significant alterations of the Greater Yellowstone Network's regional climate. Changing regional climate will, in turn, have a tremendous effect on natural systems in the GRYN (Bartlein et al. 1997, Baron 2002, Wagner 2003). It is imperative that the parks of the GRYN have a climate monitoring system in place that allows for the detection and characterization of GRYN climate change and provides climate data for use in monitoring and predicting the dynamics of other vital signs. **Monitoring objectives:** 1. Measure precipitation and air temperature in the GRYN, including BICA, GRTE, YELL and surrounding areas. 2. Measure secondary climatic elements including wind speed/direction, relative humidity, soil temperatures and incoming solar radiation in the GRYN, including BICA, GRTE, YELL and surrounding areas. **Parks where this protocol will be implemented:** BICA, GRTE and YELL
Soil structure and stability	**Protocol name:** Aridland soil structure and stability **Justification:** The National Park Service is concerned about the impacts of grazing animal populations on the structure and function of soils in Bighorn Canyon NRA. This concern is based on personal observations in the field and on the results of the rangeland health assessment of the Pryor Mountain Wild Horse Range (PMWHR) (Natural Resources Conservation Service 2004). The NRCS states that rangeland within the NRA portion of the PMWHR is in an unhealthy condition, reflecting attributes of the soils and plant communities that "may not be able to recover from degradation without energy inputs, such as mechanical alteration" (Natural Resources Conservation Service 2004). These poor soil conditions include: severe erosion, excessive loss of biological soil crust cover, and high bare soil and erosion pavement cover. The NRCS also states that "conditions are right for an explosion of noxious weeds" (Natural Resources Conservation Service 2004). Through development of a long-term monitoring protocol, we can provide more precise monitoring of soil structural and functional conditions and potentially allow for more precise correlation of soil characteristics with increases and decreases in ungulate population sizes. **Monitoring objectives:** 1. Determine the status and trend of unprotected bare soil, i.e. without biological crust cover or armoring by rocks, between vascular plants on each soil mapping unit paired both inside and outside of the Pryor Mountain Wild horse Range at three-year intervals. **Parks where this protocol will be implemented:** BICA

Vital Signs	Justification[1] and Monitoring Objectives[2]
Arid seeps and springs	**Protocol name:** Aridland seeps and springs **Justification:** Aridland seeps and springs have three unique features that separate them from the surrounding landscape – water, biologically diverse biota (some endemic) and often sustained flow duration - and underscore the importance of monitoring. Seeps and springs are often the only localized water source within a desert/arid environment during the drier periods of the year when other sources of water have diminished. Plant and insect populations thrive in seeps and springs. By supporting the base of the food chain, seeps and springs indirectly support upland communities through trophic energy transfer. Some springs support known rare, endemic flora (e.g. Sullivantia hapemanii var. hapemanii) and possibly rare invertebrates. Other fauna are strongly dependent on these scarce and vital water sources. There are threats to seeps and springs within Bighorn Canyon that could reduce their potential to support wildlife, biodiversity, and streamflow. These threats include: trampling and herbivory of vegetation and degradation of water quality by human visitors and ungulates (cattle and wild horses); and potential degradation of water quality and loss of water quantity through the influence of industrial and agricultural activities and changes in water rights both inside and outside of the NRA. **Monitoring objectives:** 1. Estimate discharge, variation in discharge and change in discharge over time of seeps and springs within BICA, taking into account seasonal annual and decadal variation. 2. Determine the status and change over time of water chemistry parameters at the orifice of seeps and springs within BICA including, but not limited to, conductivity, dissolved oxygen, pH, and water temperature. 3. Determine the status and change over time of aquatic macroinvertebrate composition along the first 100 m of runout of seeps and springs within BICA. 4. Estimate spatial extent and change in spatial extent over time of mesic vegetation along the first 100 m of runout of seeps and springs within BICA. 5. Determine species composition and change in composition over time of vegetation along the first 100 m of runout of seeps and springs within BICA. **Parks where this protocol will be implemented:** BICA.
Streamflow	**Protocol name:** Streamflow **Justification:** Streamflow measurements are useful for water quality data comparisons over time, interpretation of water quality data and calculation of parameter loads. Streamflow at any point in time is an integration of the streamflow generation and routing mechanisms in a watershed. This integration also defines the water quality at that time, including land use activities, point source discharges and natural sources (NPS 1998). Thus streamflow measurement is an essential component of water quality monitoring. Streamflow measures will help determine how water withdrawals and impoundments are influencing river and streamflow dynamics. **Monitoring objectives:** 1. Estimate trends in baseflow characteristics of rivers within or adjacent to the GRYN that are permanently gaged by the USGS. 2. Estimate trends in the timing of annual extreme water conditions of rivers within or adjacent to the GRYN that are permanently gaged by the USGS. 3. Compare annual hydrographs of rivers within or adjacent to the GRYN that are permanently gaged by the USGS. **Parks where this protocol will be implemented:** BICA, GRTE and YELL

Vital Signs	Justification[1] and Monitoring Objectives[2]
Water chemistry; *E. coli;* Aquatic invertebrate assemblages	**Protocol name:** Regulatory Water Quality **Justification:** Regulatory water quality monitoring is being conducted in response to the requirements of the Clean Water Act (CWA) and the direction of the vital signs monitoring program. The monitoring program views the monitoring of state-identified impaired waters as fulfilling the fundamental requirement of Goal 1a4 of the NPS Strategic Plan (NPS 2001b), and partially fulfilling the requirements of the Government Performance and Results Act. Four water bodies in the GRYN have been identified by the states of Montana and Wyoming (in response to the CWA) as being impaired and appear on their respective 303(d) lists. **Monitoring objectives:** 1a. Determine fecal coliform concentrations at the sampling location Shoshone River at Kane and compare to Wyoming state standards. 1b. Determine E. coli concentrations at the sampling location Shoshone River at Kane and compare to Wyoming state standards. 2a. Determine nitrate concentrations at the sampling location Bighorn River near St. Xavier and compare to Montana state standards. 2b. Determine the natural range of variability of nitrate concentrations at the sampling location Bighorn River near St. Xavier based on monthly measurements. 2c. Determine the Montana impairment score for macroinvertebrates at the sampling location Bighorn River near St. Xavier and compare to Montana state standards. 3a. Determine levels of dissolved and total metals at the sampling location Soda Butte Creek at the park boundary, both in the morning and evening at snowmelt and baseflow and compare with Montana state standards. 3b. Determine levels of metals in sediment at the sampling location Soda Butte Creek at the park boundary and compare with the probable effect concentration (PEC) at snowmelt and baseflow. 3c. Determine the diurnal variation of dissolved metals and total metals at the sampling location Soda Butte Creek at the park boundary during snowmelt and baseflow. 3d. Determine the Montana impairment score for macroinvertebrates at the sampling location Soda Butte Creek at the park boundary and compare with Montana state standards. 4a. Measure discharge continuously at Reese Creek and compare with recommended minimum flows (0.037m3/s between April 15 and October 15). **Parks where this protocol will be implemented:** BICA and YELL.

Vital Signs	Justification[1] and Monitoring Objectives[2]
Water chemistry; Aquatic invertebrate assemblages; Exotic aquatic assemblages	**Protocol name:** Integrated Water Quality **Justification:** Water quality monitoring is a fundamental tool in the management of freshwater resources. The chemical, physical and biological health of waters is considered of national value and is protected by the Federal Water Pollution Control Act. Chemical and physical tests give information that is accurate only at that moment the sample is taken. Thus the GRYN incorporates a complimentary program of chemical, physical and biological components. The use of macroinvertebrates as indicators of aquatic ecosystem health developed out of observations that specific taxa were restricted under certain environmental conditions (Richardson 1925, 1929 and Gaufin 1958). The presence of a mixed population of healthy aquatic insects usually indicates that the water quality has been good for some time. This then led to the development of list of indicator organisms and the acceptance of using macroinvertebrates for use in water quality monitoring. **Monitoring objectives:** 1. Determine the status and trend of a primary set of water chemistry parameters including, but not limited to, conductivity, dissolved oxygen, pH, water temperature and discharge in perennial surface waters of all GRYN parks. 2. Determine levels of substrate composition and embeddedness in perennial surface waters of GRYN parks. 3. Determine the status and trend in benthic macroinvertebrate communities in flowing perennial in surface waters of GRYN. 4. Determine the status and trend in the acid-neutralizing capacity of high-risk alpine lakes of the GRYN and estimate the rate at which water chemistry is changing over time. 5. Determine concentrations of polycyclic aromatic hydrocarbons (PAHs) and other constituents associated with two-stroke and four-stroke engines at targeted marinas within GRYN. 6. Determine input of nutrient enrichment and wastewater effluents through analysis of fecal coliform bacteria and macroinvertebrate communities at a small number of targeted sites of high concern within the GRYN. 7. To detect occurrence of aquatic invasive plant and animal species at select targeted locations most susceptible to initial invasion (marinas, areas of high fishing access, etc.) with an emphasis on areas that coincide with water quality monitoring samples with GRYN. **Parks where this protocol will be implemented:** BICA, GRTE and YELL
Whitebark pine	**Protocol name:** Whitebark pine **Justification:** Whitebark pine is a “keystone” species throughout the Greater Yellowstone Ecosystem, the cones of which serve as a major food source for grizzly bears and other species. Whitebark pine stands have been decimated in areas of the Cascades and northern Rocky Mountains due to the introduction of an exotic fungus—white pine blister rust—as well as mountain pine beetles. This vital sign is intended to estimate current status of whitebark pine relative to infection with white pine blister rust as well as to assess the vital rates that would enable us to determine the probability of whitebark pines persisting in the Greater Yellowstone Ecosystem. **Monitoring objectives:** 1. Estimate the proportion of whitebark pine trees within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests) infected with white pine blister rust, and to determine whether that proportion is changing over time. 2. Determine the relative severity of white pine blister rust infection in trees > 1.4 m in height within stands of infected whitebark pine within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests). Severity is indicated by the number and location (trunk or branch) of blister rust cankers. 3. Estimate the survival of individual whitebark pine trees > 1.4 m in height within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests), explicitly taking into account the severity of infection with white pine blister rust (from objective 2). **Parks where this protocol will be implemented:** GRTE and YELL

Vital Signs	Justification[1] and Monitoring Objectives[2]
Invasive plants	**Protocol name:** Invasive plants **Justification:** There is a strong consensus among scientists around the world that, after habitat loss and landscape fragmentation, the second most important cause of biodiversity loss now and in the coming decades is invasion by alien plant, animal and other species (Allendorf and Lundquist 2003, Chornesky and Randall 2003, Walker and Steffen 1997). In all of the parks, exotic plant species are a serious threat to natural and cultural resources. Terrestrial exotic plants have replaced native vegetation in large areas of Grand Teton and Bighorn Canyon, are widespread in the Northern Range of Yellowstone, and there is an ongoing threat of further displacement. This displacement affects not only native vegetative community structure, composition and succession, but can also cause extirpation or extinction of endemic and/or endangered plant species (Walker and Smith 1997, Mack et al. 2000). Exotic plants that become invasive, aggressive and widespread create detrimental impacts on animal habitat and nutrition, soil nutrient cycling and fire and flood processes in parks (DiTomaso 2000, Goodwin 1992, Mack et al. 2000). NPS management policy states that native species will not be allowed to be displaced by exotic species if displacement can be prevented (National Park Service (US) 2001a) **Monitoring objectives:** 1. Detect occurrences of invasive exotic plants new to the parks (currently on the GRYN watch list) before they become viable populations. 2. Detect new occurrences of high priority (1-3) invasive exotic plants in weed-free zones of the park before they become viable populations. 3. Determine status and trend of high priority (GRYN priority 1-3 species) invasive exotic plants outside of control boundaries at 5 year intervals. 4. Determine distribution and abundance of exotic plants (GRYN priority 4-5 species) at 5 year intervals. 5. Determine status and trend of selected native plant community and ecosystem attributes at locations (e.g. in targeted habitats) infested with invasive exotic plants (GRYN priority 4 species) and compare with similar sites not infested with invasive exotic plants at 5 year intervals. 6. Determine status and trend of native plant community and ecosystem attributes at locations where selected invasive species have been treated/controlled and compare with similar sites not infested with invasive exotic plants at 5 year intervals. **Parks where this protocol will be implemented:** BICA, GRTE and YELL
Amphibians	**Protocol name:** Amphibians **Justification:** Declines in the abundance and distribution of amphibians have been widely recognized as an emerging issue (Stuart et al. 2004). Concerns regarding such declines resulted in the funding of the Amphibian Research and Monitoring Initiative (ARMI) in 2000. Specific objectives of the GRYN are intended to determine if the occurrence of amphibians is decreasing and if there is any evidence regarding likely underlying causes of any observed declines that might warrant further directed research or management actions consistent with the NPS management policies. **Monitoring objectives:** 1. Estimate the proportion of catchments (approximately 8th order) within YELL and GRTE used for breeding by each species of amphibian (other than Boreal toads) and to estimate the rate at which use of these sites for breeding is changing over time. 2. Estimate the proportion of catchments (approximately 8th order) and targeted breeding sites within YELL and GRTE used for breeding by boreal toads (Bufo boreas) and to estimate changes in occupancy of targeted breeding sites over time. 3. Estimate the proportion of potential breeding sites (i.e. wetlands) that are minimally suitable for breeding (i.e., have standing water) in any given year. Parks where this protocol will be implemented: BICA, GRTE and YELL

<table>
<tr><th>Vital Signs</th><th>Justification[1] and Monitoring Objectives[2]</th></tr>
<tr><td>Landbirds</td><td>Protocol name: Landbirds

Justification: Protection of native species and their habitats is one of the primary challenges outlined in the NPS Natural Resource Challenge (National Park Service (1999). The National Park Service Inventory and Monitoring Guidelines (NPS-75) further states that “Preserving the natural resources (and natural processes) in the national parks may be the most important legacy the Park Service can provide American conservation.” Thus, monitoring the composition of native communities of concern and the changes occurring within and among these communities is essential to meeting our Natural Resource Challenge. Because of the large number of habitat types within the Greater Yellowstone Network (GRYN) and the enormous variability within these habitat types, our initial efforts on landbirds will focus on estimating the status and trends of landbirds within four habitats (communities) of concern: alpine, aspen, shrub steppe (sage), and riparian.

Monitoring objectives:
1. Estimate the proportion of sites occupied (MacKenzie et al. 2002) in habitats of concern in BICA, GRTE, and YELL and to estimate the changes in occupancy over time. Although we will estimate occupancy and changes in occupancy for all species with sufficient data, our emphasis will be species identified as dependent on or obligates of the particular habitat of concern.
2. Estimate the abundance (density) of birds in habitats of concern in BICA, GRTE, and YELL and to estimate the changes in abundance over time.
3. Estimate community composition and associated parameters of landbirds in habitats of concern in BICA, GRTE, and YELL and to estimate trends in these parameters over time. Specific parameters to be estimated include, but are not limited to, species richness and relative species richness (e.g., richness of native to exotic species).

Parks where this protocol will be implemented: BICA, GRTE and YELL</td></tr>
<tr><td>Land use</td><td>Protocol name: Land use

Justification: Land use activities surrounding park borders can significantly influence the status of ecological condition and functioning within parks. The GRYN has identified land use change as a top priority vital sign for defining ecosystem health within parks. Long-term monitoring of land use activities surrounding parks of the GRYN will provide information on trends in land use and land cover change, and allow for analyses which quantify potential consequences for park resources. This will provide managers with the scientific background for incorporating the consequences of surrounding land use activities into park management decisions.

Monitoring objectives:
1. Determine the density and location of homes on private and public lands within the 20 counties comprising the Greater Yellowstone Ecosystem (Rasker 1991) plus two additional counties surrounding BICA and measure change over time.
2. To determine the number, length and type (i.e. size) of roads within 22 counties within and surrounding the GRYN, as well as measure changes in the existence and characteristics of roads over time.

Parks where this protocol will be implemented: BICA, GRTE and YELL</td></tr>
</table>

[1] Justification for individual objectives is provided in the protocols and protocol development summaries (Appendix VI).

[2] Specific objectives presented here are in abbreviated form. Details about targeted populations, scales, state variables, etc are presented within a given protocol. Some monitoring objectives, such as those for invasive plants, require further refinement and possible reductions.